WE CLAIM:

1. A superalloy component having a ceramic thermal barrier coating on at least a portion of its surface, comprising:

a superalloy substrate;

a ceramic coating overlying the superalloy substrate, the ceramic coating having a plurality of gaps between a plurality of columns; and

an inorganic layer overlying the ceramic coating and conformally coating the plurality of gaps;

wherein the inorganic layer is deposited over the ceramic coating by atomic layer deposition.

2. The superalloy component of claim 1, further comprising a bonding coat located between the superalloy substrate and the ceramic coating;

wherein the bonding coat is deposited over the superalloy substrate by atomic layer deposition.

3. The superalloy component of claim 1, wherein the plurality of gaps are micron sized gaps.

4. The superalloy component of claim 1, wherein the plurality of gaps are sub-micron sized gaps.

5. The superalloy component of claim 1, wherein the ceramic coating comprises yttria-stabilized zirconia.

6. The superalloy component of claim 1, wherein the ceramic coating comprises tantalum oxide (Ta_2O_5).

7. The superalloy component of claim 1, wherein the inorganic layer comprises a substance selected from the group consisting of oxides, nitrides, metal films, metal alloy films, and nano-laminates thereof.

8. The superalloy component of claim 1, wherein the inorganic layer comprises a compound of Al, Hf, Si, Ln (rare earth including entire lanthanum series, scandium and yttrium), Mg, Mo, Ni, Nb, Sr, or Ti.

9. The superalloy component of claim 8, wherein the inorganic layer comprises a substance selected from the group consisting of aluminum oxide (Al_2O_3), tantalum oxide (Ta_2O_5), hafnium oxide (HfO_2), mixtures thereof, and nano-laminates thereof.

10. A superalloy component having a ceramic thermal barrier coating on at least a portion of its surface, comprising:

a superalloy substrate;

an yttria-stabilized zirconia layer overlying the superalloy substrate, the yttria-stabilized zirconia layer having a plurality of gaps between a plurality of columns; and

an aluminum oxide (Al_2O_3) layer overlying the yttria-stabilized zirconia layer, conformally coating the plurality of gaps;

wherein the aluminum oxide (Al_2O_3) layer is deposited over the yttria-stabilized zirconia layer by atomic layer deposition.

11. The superalloy component of claim 10, further comprising a bonding coat located between the superalloy substrate and the yttria-stabilized zirconia layer;

wherein the bonding coat is deposited over the superalloy substrate by atomic layer deposition.

12. The superalloy component of claim 10, wherein the plurality of gaps are micron sized gaps.

13. The superalloy component of claim 10, wherein the plurality of gaps are sub-micron sized gaps.

14. The superalloy component of claim 10, wherein the ceramic coating comprises yttria-stabilized zirconia.

15. The superalloy component of claim 10, wherein the inorganic layer comprises a substance selected from the group consisting of oxides, nitrides, metal films, metal alloy films, and nano-laminates thereof.

16. The superalloy component of claim 10, wherein the inorganic layer comprises a compound of Al, Hf, Si, Ln (rare earth including entire lanthanum series, scandium and yttrium) Mg, Mo, Ni, Nb, Sr, or Ti .

17. The superalloy component of claim 16, wherein the inorganic layer comprises a substance selected from the group consisting of aluminum oxide (Al_2O_3), tantalum oxide (Ta_2O_5), hafnium oxide (HfO_2), alloys thereof, and nano-laminates thereof.

18. A component having a ceramic environmental barrier coating on at least a portion of its surface, comprising:

a silicon-based substrate;

a tantalum oxide (Ta_2O_5) layer overlying the silicon-based substrate having a plurality of gaps between a plurality of columns; and

an aluminum oxide (Al_2O_3) layer overlying the tantalum oxide (Ta_2O_5) layer, conformally coating the plurality of gaps;

wherein the aluminum oxide (Al_2O_3) layer is deposited over the tantalum oxide (Ta_2O_5) layer by atomic layer deposition.

19. The component of claim 18, further comprising a bonding coat located between the silicon-based substrate and the tantalum oxide (Ta_2O_5) layer;

wherein the bonding coat is deposited over the silicon-based substrate by atomic layer deposition.

20. The component of claim 18, wherein the plurality of gaps are micron sized gaps.

21. The component of claim 18, wherein the plurality of gaps are sub-micron sized gaps.

22. The component of claim 18, wherein the plurality of micron sized gaps extend from the top surface of the tantalum oxide (Ta_2O_5) layer towards the silicon-based substrate.

23. The component of claim 18, wherein the ceramic environmental barrier coating has a thickness of about 0.05 mm to about 1.3 mm.

24. The component of claim 18, wherein the aluminum oxide (Al_2O_3) layer is at a thickness in the range of about 5 nm to about 5,000 nm

25. The component of claim 24, wherein the aluminum oxide (Al_2O_3) layer is at a thickness in the range of about 5 nm to about 2,500 nm.

26. A superalloy component having a ceramic thermal barrier coating on at least a portion of its surface, comprising:

a superalloy substrate;

a ceramic thermal barrier coating overlying the superalloy substrate;

a first coating layer overlying the ceramic thermal barrier coating;

the first coating layer having a thickness from about 5 nm to 5000 nm microns;

the ceramic thermal barrier coating having a plurality of gaps extending from the top surface of the ceramic thermal barrier coating towards the substrate and defining a plurality of columns of the ceramic thermal barrier coating; and

a second coating layer overlying the first coating layer and conformally coating the plurality of gaps;

wherein the second coating layer is deposited over the first coating layer by atomic layer deposition.

27. The superalloy component of claim 26, further comprising a bonding coat located between the superalloy substrate and the first coating layer;

wherein the bonding coat is deposited over the superalloy substrate by atomic layer deposition.

28. The superalloy component of claim 26, wherein the plurality of gaps are micron sized gaps.

29. The superalloy component of claim 26, wherein the plurality of gaps are sub-micron sized gaps.

30. The superalloy component of claim 26, wherein the first coating layer and the second coating layer are selected from the group consisting of oxides, carbides, nitrides, silicides, and metals.

31. The superalloy component of claim 30, wherein the oxides are selected from the group consisting of Al_2O_3, Cr_2O_3, Sc_2O_3, SiO_2, ZrO_2, and Ta_2O_5. HfO_2, TiO_2, Ln_2O_3, MgO, SrO, and alloys and compounds thereof.

32. The superalloy component of claim 30, wherein the nitrides are selected from the group consisting of TaN, ZrN, HfN, TiN, Si_3N_4 and alloys and compounds thereof.

33. The superalloy component of claim 30, wherein the carbides are selected from the group consisting of SiC, TaC, ZrC, HfC and alloys and compounds thereof.

34. The superalloy component of claim 30, wherein the silicides are selected from the group consisting of $MoSi_2$, Mo_5Si_3, $TaSi_2$, Ta_5Si_3, and alloys and compounds thereof.

35. The superalloy component of claim 30, wherein the metals are selected from the group consisting of Pt, Ru, Rd, Ir, and alloys and compounds thereof.

36. A method for coating a silicon-based substrate, comprising:

depositing a tantalum oxide (Ta_2O_5) layer onto a silicon-based substrate, by electron beam physical vapor deposition, such that the tantalum oxide (Ta_2O_5) layer is in the form of columnar grains; and

depositing an inorganic layer, by atomic layer deposition, onto the tantalum oxide (Ta_2O_5) layer, such that the inorganic layer is uniform and conformal.

37. The method of claim 36, further comprising depositing a bonding coat onto the silicon-based substrate, by atomic layer deposition, before depositing the tantalum oxide (Ta_2O_5) layer.

38. The method of claim 36, wherein the inorganic layer is selected from the group consisting of aluminum oxide (Al_2O_3), tantalum carbide (TaC), hafnium oxide (HfO_2), mixtures thereof, nano-laminates thereof, and alloys thereof.

39. The method of claim 36, wherein the inorganic layer is selected from the group consisting of silicon carbide (SiC), silicon nitride (Si_3N_4), oxycarbides, carbonitrides, mixtures thereof, nano-laminates thereof, and alloys thereof.

40. The method according to claim 36, wherein the silicon-based substrate is one of a silicon nitride substrate and a silicon carbide substrate.

41. A method for coating nickel-based superalloy gas turbine components, comprising:

depositing an yttria-stabilized zirconia layer onto a nickel superalloy turbine component, by electron beam plasma vapor deposition, such that the yttria-stabilized zirconia layer is in the form of columnar grains; and

depositing an inorganic layer, by atomic layer deposition, onto the yttria-stabilized zirconia layer, such that the inorganic layer is uniform and conformal.

42. The method of claim 41, further comprising depositing a bonding coat onto the nickel superalloy turbine component, by atomic layer deposition, before depositing the yttria-stabilized zirconia layer.

43. The method of claim 41, wherein the inorganic layer is selected from the group consisting of aluminum oxide (Al_2O_3), tantalum carbide (TaC), tantalum oxide (Ta_2O_5), hafnium oxide (HfO_2), mixtures thereof, nano-laminates thereof, and alloys thereof.

44. The method of claim 41, wherein the inorganic layer is selected from the group consisting of silicon carbide (SiC), silicon nitride (Si_3N_4), oxycarbides, carbonitrides, mixtures thereof, nano-laminates thereof, and alloys thereof.

45. The method of claim 41, wherein the nickel-based superalloy gas turbine component comprises an article selected from the group consisting of a turbine blade, a turbine vane, a combustor fuel nozzle, and a combustor shield.

46. The method of claim 41, wherein the inorganic layer comprises platinum.

47. A method for coating a substrate comprising:

etching chemically a thermal barrier coating such that the thermal barrier coating is in the form of columnar grains; and

depositing an inorganic layer, by atomic layer deposition, onto the thermal barrier coating, such that the inorganic layer is uniform and conformal.

48. The method of claim 47, wherein the inorganic layer is selected from the group consisting of aluminum oxide (Al_2O_3), tantalum carbide (TaC), hafnium oxide (HfO_2), mixtures thereof, nano-laminates thereof, and alloys thereof.

49. The method of claim 47, wherein the inorganic layer is selected from the group consisting of silicon carbide (SiC), silicon nitride (Si_3N_4), oxycarbides, carbonitrides, mixtures thereof, nano-laminates thereof, and alloys thereof.